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Implementing manufacturing system technologies within a CIM environment /

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IMPLEMENTING MANUFACTURING SYSTEM TECHNOLOGIES WITHIN A CIM ENVIRONMENT

by

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Abstract

This thesis proposes a strategy that stresses the need for integration when selecting, implementing and evaluating a computer aided manufacturing (CAM) system. The strategy includes criteria for the selection of a system, as well as procedures for implementation. Methods for evaluating system performance after implementation are also addressed.

The objective of this thesis is to develop a structured methodology for the implementation of a CAM system as part of an overall computer integrated manufacturing (CIM) plan. The impetus behind this strategy is the need to integrate the various disciplines within a company to attain the true benefits of computer automation. In developing this methodology, the hypothesis was made that a comprehensive implementation strategy is required to effectively implement a CAM system and ensure integration within a CIM structure.

Finally, the methodology developed is applied to the implementation of a CAM system by a small manufacturing company. The results of this case study support the need for a comprehensive strategy for the selection and implementation of a CAM system to ensure integration with existing and future systems.

Chapter 1 Introduction

Spurred by increased competition from abroad, American manufacturing is investing in CIM technologies to increase productivity. (Gopal, 1986) However, simply investing in leading edge CIM technologies does not seem to be the answer. The productivity improvements come from the successful implementation of these systems. An article in the New York Times addresses this problem stating that the Japanese are investing in these same American developed technologies but are implementing them more effectively in their factories and thus achieving greater productivity.

> American manufacturers have long comforted themselves with the knowledge that the United States leads the world in the development of new manufacturing technology. Many of them believe they can use that lead to gain a competitive edge on foreign rivals.
>
> There has been plenty of anecdotal and stastical evidence, however, that Americans have been just as likely to shoot themselves in the foot with the new technology as to knock off their competitors. (Feder,1987)

In theory, CIM refers to a process continuum where computer technology is applied to the design, manufacture and marketing of a product for a profit. Unfortunately however, CIM is typically implemented piecemeal in existing manufacturing operations to minimize production disruption and to spread the cost. This often results in the development of a series of "islands of automation" rather than an integrated continuum. (Hinmon, 1987)

When implementing CIM technologies, companies must understand the need to review the current organizational structure and operating procedures, making the necessary modifications to bridge the gap between these "islands" and achieve the maximum benefits from the new automated system. For CIM to be really productive, information must be seen as a global, company-wide resource, not as a collection of fragments of data, each of which is the jealously guarded property of a particular department. For this to be possible, company structure must change to reflect the change in the way information is treated. (McDonald, 1984) Investing in CIM technologies without any regard for the business changes that must be effected will minimize the benefits of the new automated methods, perpetuating the shortcomings of the manual system.

This thesis primarily deals with the implementation of computer aided manufacturing system for N/C toolpath creation, stressing the need for integration within an existing CIM environment. However, the concepts developed here can be applied to the implementation of various Computer-Aided Manufacturing technologies.

Definition of Terms

Computer Integrated Manufacturing (CIM) encompasses all aspects of a business, from order entry to production scheduling on the shop floor. In essence, a true CIM system completely automates the flow of information within a company, so that when a customer adds 1000 units to an existing order the shop foreman will immediately be alerted to reallocate production resources. The National Research Council has compelling statistics showing that CIM can significantly reduce design costs, lead times, and work in-process while offering unprecendented improvements in production productivity, product quality, design analysis and asset utilization. (Weimer, G., Knill, B., and Mills, R., 1987)

Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) are subsets of CIM. Computer Aided Design can be defined as the use of computer systems to assist in the creation, modification, analysis or optimization of a design. (Groover & Zimmers, 1984)

Typical functions associated with CAD are:

Wire-frame design
Finite element analysis
Drafting and documentation creation
Design and simulation of mechanisms
Mass properties analysis
Solids modeling

CAM can be defined as the use of computers to support the production processes that will transform raw materials into the finished product. (CASA/SME, 1985) The first application of Computer Aided Manufacturing (CAM) was numerical control machine tools in the late 1950's. Since then, CAM has spread into many other areas of manufacturing. Some typical CAM functions include:

Computer numerical control
Computer aided process planning
Robotics
Computer aided quality control
Computer aided production scheduling

CAM has brought tremendous improvements in productivity and flexibility to the batch manufacturing process by enhancing the ability to handle information and control processes. (CASA/SME, 1985)

Chapter 2 Problem Statement

Despite the increasing investment in CIM technologies, many companies are failing to achieve the maximum benefits attainable from these systems. (Feder, 1987) This can be attributed to the lack of an enterprize-wide strategy for selecting, implementing and evaluating computer based systems. The following is a discussion of some of the problems associated specifically with CAM system implementations.

It is generally felt that there are many different CAM systems on the market today and no one system is the best for all applications. Simply investing in the most expensive system available will in no way ensure the productivity benefits that are advertised by the vendor. (Knox, 1983) Companies must understand the need to develop a system selection strategy well in advance of the planned investment.

As a result of increasing power and falling cost of computer hardware and software, it is now apparent that before long all operations within a manufacturing company will become computer assisted. (Stark, 1986) As the different sections of the manufacturing environment become automated, it is important to ensure that information can flow smoothly between them. Unfortunately, the traditional separation between design and manufacturing has in many cases extended into the computer age. In many companies, engineering and manufacturing have separate computers and unique data bases which increases the communication gap between the two. (Knox,1983)

In addition, the implementation of computer aided methods will effect manual operating procedures. A strategy must be developed to modify old procedures and establish new ones so that the system is utilized most effectively. Lack of management committment, foresight and willingness to carry through these changes, required by extensive use of computer-based methods, are the major causes of unproductive use of CIM technologies. Computer technology has advanced at such a rapid rate that many managers have not been properly educated in the application or management of computer assisted methods. (Stark, 1986)

Finally, many companies fail to establish effective procedures for monitoring system performance after a system has been implemented. To accomplish this standard procedures must be developed for system evaluation. (Quantz, 1984)

Chapter 3 Approach to Problem Solution

To address the problems associated with the implementation of this technology, a methodology was developed based on the assumption that typical problems encountered during implementation can be traced back to the lack of a pre-defined strategy for CAM system selection and implementation. The methodology developed concentrated on the following three areas:

I. CAM System Selection
II. CAM System Implementation
III. CAM System Evaluation

Educating employees on system capabilities and establishing a commitment to a successful implementation are two factors critical to the success of this strategy. Although system costs are often cited as the major obstacle to implementing a CAM system, inertia and middle management reluctance to change are often the real reasons. (Quantz, 1984)

The first portion of this methodology addressed the CAM system selection process. The selection process developed included the assessment of automation needs to ensure an appropriate system selection along with CIM plan development, stressing the need for integration. The final portion of the selection procedure concentrated on establishing system evaluation criteria and benchmarking procedures.

The second phase of the methodology developed procedures for implementing and integrating the CAM system within a CIM network. The system management function and associated responsibilities were discussed in addition to management and user training considerations. The major portion of the implementation phase dealt with the development of standard practices and procedures to facilitate effective utilization of the CAM system. The implementation of the CAM system will effect the flow of information between engineering and manufacturing. Company practices and procedures must be modified to reflect these changes in order for the implementation to be successful. (Hardeski, 1986)

The final phase of the methodology addressed procedures for evaluating system performance after implementation. Providing a verifiable means of user feedback is necessary to monitor system performance. (Quantz, 1984) Figure 1 outlines the structure of the proposed methodology.

FIGURE 1

OUTLINE OF IMPLEMENTATION METHODOLOGY

SYSTEM SELECTION

- ASSESSING AUTOMATION NEEDS
- DEVELOPING A CIM PLAN
- ESTABLISHING EVALUATION CRITERIA
- SYSTEM BENCHMARKING

SYSTEM IMPLEMENTATION

- SYSTEM MANAGEMENT
- SITE PREPARATION
- TRAINING
- STANDARDS & PROCEDURES
  - FILE STORAGE
  - REVISION CONTROL
  - CAD STANDARDS
  - DOCUMENTATION STANDARDS
  - OLD PROGRAM CONVERSION
  - INITIAL PROJECT SELECTION

SYSTEM EVALUATION

- SYSTEM SCHEDULING
- USER LOG
- USER SUPPORT
- EVALUATING PERFORMANCE

Chapter 4 — CAM System Selection

The following section of this thesis deals with the CAM system selection process. The proposed methodology for system selection is broken down into the following four tasks:

Assessing automation needs
Developing a CIM plan
Establishing evaluation criteria
System benchmarking

Approximately 75% of the system selection effort should be spent on automation needs assessment and CIM plan development. (Thomson, 1984) If these two tasks are performed properly, the remaining two will be comparatively easy.

Task 1: Assessing Automation Needs

The importance of this first step in the system selection process can not be over emphasized. Too often companies invest in CIM technologies before investigating the automation needs of the corporation. This leads to improper technology selection with systems that solve subsets of a bigger problem. (CASA/SME, 1985)

The first step in assessing automation needs is the definition of corporate objectives. It is important for management to clearly define the goals it intends to achieve with computer aided methods. Typical goals might be: lower production costs, greater flexibility, decreased prototype cycle time, improved design storage and retrieval. (Hewlett Packard Co., 1985)

The next step is to perform an "As Is" analysis on the operation which is to be automated. The current information flow of the operation to be automated must be fully understood. This includes the way information is received and output as well as the flow within the particular operation. This analysis will highlight any barriers to automation which must be considered in the decision to automate. It will also pinpoint requirements for the system to be successfully integrated into an existing company wide information network. Finally, the study of the current information flow and how it will be affected by the implementation of computer aided methods will be very useful during the restructuring of the staff organization to manage the new technology. (Duane, Madden, 1984)

To perform this analysis, a company task force should be assembled. The task force should consist of one member of each department, preferably a department manager effected by the implementation of the new technology. The people who will be working with the system on a daily basis should also be represented on the task force. Involving the people effected by the system implementation will help to minimize their reluctance to change current practices by showing them how the new system is going to make their job easier. This involvement will also maximize their acceptance of the system by making them part of the selection process. (Weimer, Knill, Mills, 1987) If no one in the company is familiar with computer technology or automation techniques, the company should hire an outside consultant as a member of the task force. The task force will report to and receive direction from upper management, who should possess a global picture of the company operations and the goals to be achieved.

With the "As Is" analysis complete, the task force must now perform a "Needs" analysis to assess the company's automation needs. This will require that the members of the task force become familiar with the technology that is currently available and the latest trends associated with the technology. This can be accomplished by attending trade shows, seminars, visiting company or university sites and simply reading vendor brochures. Using the information gained from the "As Is" analysis and keeping the company goals in mind, the task force must then evaluate which technologies are appropriate for their company and how they can be best applied.

Task 2: Developing a CIM Plan

The choice to implement CIM poses a company with a major investment that will bring about many organizational changes. Before making these investments, management must plan for the inevitable changes and set goals to strive for after system implementation. Planning for organizational changes will ease the transition from manual to computer assisted methods. (Hewlett Packard Co., 1985) An integral part of this plan is educating personnel on the new technology to ensure their acceptance of the system and enable them to effectively manage it. This can be accomplished by having employees attend a seminar on CIM that will give them a better understanding of the technology and help them establish realistic expectations of system performance. This is especially important for company employees who have heard all the sales hype that often overstates system capabilities. If these employees go into the implementation process with unrealistic expectations, they will form a lasting negative impression of the system which will spread to the other employees.

Management must also plan for system growth, stressing the goal of integration. As the company's CIM architecture grows, it is important to ensure that all the pieces will fit together to form a unified information network. (Appleton, 1985) It is through integration that the real benefits of CIM are obtained. The CIM plan will act as a road map from which the company can chart a structured and coordinated approach toward a unified CIM system.

Task 3: Establishing Evaluation Criteria

From the information gathered in the first two steps, the task force can begin to develop specific evaluation criteria to select a CAM system. Using the knowledge gained at seminars or trade shows, the task force can establish an initial list of approximately ten vendors that can fulfill the identified automation needs and meet the basic criteria established in the CIM plan. This list is often referred to as the long list.

The next step is for the task force to develop a technical specification that will describe the specific functional requirements and capabilities of the systems to be proposed by the vendors on the long list. Again, the knowledge obtained during the research stage should be used to complete this specification. Preparing a technical specification is an important part of the CAM system selection process that serves many purposes. The first and most obvious purpose is that it can be used to solicit system proposals from the vendors on the long list. The vendors will be more than happy to receive a well written technical specification because it signifies that they are dealing with an educated customer and half of their sales effort has been completed for them. Preparing the specification can also be thought of as part of the educational process in that it makes members of the task force more aware of current capabilities of CAD/CAM systems and the required characteristics necessary for the system to perform effectively in their operating environment. Finally, the technical specification is used as a guide during the development of the system benchmark. (Dow, 1984)

However, when preparing the technical specification, it is important not to become too detailed. For example, a specification should not list 15 different ways that the proposed system must be able to create a line or 20 ways that it must be able to create a note. Vendors find specifications such as these tiresome and will often ignore them when submitting a proposal. The specifications should be written in a simple and concise manner describing the companies wants and needs, not how lines and notes should be created. These methods will be evaluated at the system benchmark. Once the technical specification is complete, it should be submitted to all vendors on the long list simultaneously, giving them sufficient time to prepare system proposals. A task force member who is well versed in CAD/CAM technology, should be selected as the vendor contact to answer any questions that will arise during vendor review of the specification. List 1 depicts a typical outline for a technical specification.

Task 4: System Benchmarking

Having successfully completed the first three steps, the process of benchmarking systems should be very straightforward. After reviewing the proposals returned by the vendors on the long list, the task force should have narrowed down the long list to approximately five potential vendors. This is commonly referred to as the short list.

LIST 1

Outline for Technical Specifications Document (McDonald, 1984)

1. Introduction
2. Intended System Use
3. Current Methods of Operation
4. Anticipated Method of CAM System Operation
5. Software Requirements
6. Hardware Requirements
7. Maintenance Requirements
8. Training Requirements
9. System Warranty and Acceptance Requirements
10. Vendor Objective Statement

The task force must now prepare a benchmark as a final evaluation before making the system selection. A benchmark should be performed even if there is only one vendor on the short list to confirm the systems capabilities. A good benchmark should consist of work typically done by the company. The benchmark should be reasonably difficult but should not require an excessive amount of time. It is important to keep in mind that the purpose of the benchmark is to test the system, not the operator. For this reason, there should not be a lot of emphasis placed on the time required by the operator to complete the benchmark. Instead, the evaluation team should be concentrating on the following:

User interface
Menu or command structure
File structure
Ability to grow and customize the system
Hardware capabilities
Maintenance requirements
State of technology

Based on information gathered from technology publications and trade shows, the evaluation team must determine if the vendors hardware and software is current with the state of the art computer technology. They must also evaluate the vendors committment to update system capabilities to remain current with the ever changing state of computer technology.

The task force should make it clear to the vendors on the short list that one of the requirements of the benchmark is that it be performed on a the same system configuration that was listed in the vendor proposal. The vendors are naturally going to want to demonstrate their software on their fastest computer and their flashiest workstation.

This tends to bias the evaluation because the operator will try to impress the customer with the capabilities of the advanced hardware and the customer assumes that the hardware mentioned in the proposal has the same capabilities. Figure 2 shows a typical evaluation form with weights attached to each of the system features. This is an effective way of matching system capabilities with company needs during a benchmark.

After benchmarking the systems on the short list, members of the task force should visit customer sites of the vendors they were most impressed with. (Dow, 1984) The vendor should be more than willing to let you visit a customer site. If not, this should raise some serious questions about the vendor's level of customer satisfaction. Visiting a customer site provides an excellent opportunity to investigate the vendor's customer service record and get some ideas on system

FIGURE 2

SAMPLE SYSTEM EVALUATION FORM

SYSTEM CAPABILITIES	WEIGHT(0-1)	SCORE(0-10)
USER INTERFACE -EASE OF USE -DISPLAY QUALITY -MENU/COMMAND STRUCTURE -ON-LINE HELP	.7	6
SYSTEM FUNCTIONS -TOOLPATH GENERATION -MACRO CAPABILITIES -POST PROCESSORS -DATA BASE STRUCTURE -MAINTENANCE REQUIREMENTS	1.0	8
SYSTEM TRAINING -TRAINING AVAILABLE -ABILITY TO CUSTOMIZE	.9	4
INTEGRATION -ABILITY TO INTERFACE WITH EXISTING AND FUTURE SYSTEMS	.8	8
STATE OF TECHNOLOGY	.9	7
VENDOR SUPPORT	.7	3

TOTAL= (WEIGHT)(SCORE) 30.6

implementation. List 2 provides some typical questions to ask at a user site.

Once these tasks have been completed the evaluation team is ready to make an educated decision on a CAM system selection. After the final selection has been made, the company should try to negotiate a payment plan that spreads out over the length of the implementation period. The payments will be contingent on the satisfactory installation and start up of the system. This will make it easier for the company to maintain the vendor's support during the inevitable problems that occur during a system start up.

LIST 2

Questions for Site Visitation

-What were the deciding factors behind the system selection?

-How long did the installation take and how well did it go?

-Does the system meet the company's needs?

-Were modifications necessary? If so, did the vendor offer support?

-Did the company have a predetermined plan for implementation?

-What was the time frame for the implementation?

-Did the company have professional guidance from a consultant?

-How was the system training performed? Was it successful?

-What were managements expectations going into the implementation? Were they realized?

Chapter 5 CAM System Implementation

The first computers commercially available in the 1950's were large expensive machines that were hard to use and manage. These machines were initially purchased to perform data processing operations. MIS/DP (Management Information Systems/ Data Processing) groups evolved to manage these large computer systems and became the central supplier of computing services to the corporation. Problems developed as the different functional groups within the organization began to compete for computing resources. (CASA/SME, 1985)

With the development of the minicomputer in the 1970's, the functional groups within companies began purchasing minicomputers dedicated to their specific needs. As the cost of computer hardware continued to decline more and more departments invested in computer solutions customized to meet their specific functional requirements. (CASA/SME, 1985) This lead to the "Islands of Automation" that exist in many organizations today. These "Islands of Automation" pose a new problem to the corporation, that of integration. Most often the systems purchased by the individual groups consist of dissimiliar hardware and software making the transfer of information between the systems difficult and inefficient. In addition each of the individual systems developed a unique data base which often contained redundant information. Without an effective means of transferring information between systems, the main purpose of CIM, improved communication, will be defeated. (Stark, 1986)

The successful implementation of the CAM system is the primary concern of the system manager whose responsibilities will range from site preparation before installation, to monitoring system performance after implementation. The following section develops a methodology for system implementation, highlighting the changes that must be implemented on a functional level to effectively utilize the new system. This methodology covers the following areas:

I. System Management
II. Site Preparation
III. Training
IV. Standards and Procedures

I. System Management

Before the system is installed a strategy for managing the new computer system should be resolved. The manager of the system will be responsible for scheduling and allocating system resources, maintaining the system (System backup, data base management), establishing standard procedures for system use and monitoring system performance. The following section discusses two possible management strategies to accomplish this task, functional management and MIS/DP(Management information systems/Data processing) management

Functional Management

A functional management strategy would require that the system be managed by the functional department (ie. Engineering, Manufacturing) that will be using the system. Functional managers would have a much better understanding of the requirements that the system must fulfill and how it must interface to other computerized and non-computerized operations within the company. (Duane, Madden, 1984) This knowledge will better enable them to establish standard procedures for effective system operation. In addition, department managers will be more aware of project deadlines allowing them to reschedule system resources to meet critical deadlines. With a better understanding of the functional task, it will also be easier for department managers to moniter system productivity and spot inefficiencies. A weakness of functional management strategy would be the task of system management which includes performing system backups, managing the data base, solving system problems etc. On older and larger computer systems, these can be complex and time consuming tasks. However, as computer systems have developed, they have become much easier to maintain, simplifying many of the above tasks and decreasing the amount of skill and effort required to maintain them. (Duane, Madden, 1984)

MIS/DP Management

This strategy is most often used by large companies that employ mainframe computer systems to support many users on-site as well as at remote sites. The task of managing systems such as these which have large complex databases, requires a full time MIS/DP group. (Duane, Madden, 1984) In this situation it would be more efficient to have the MIS/DP group manage the CAD/CAM system rather than duplicate their knowledge and experience at the functional level. It is important for the MIS/DP group to work in close interaction with the functional groups they support in order for this strategy to be successful.

Other than the situation just described it is felt that a functional management strategy is the preferred way to implement and manage a CAD/CAM system, because of the improved user friendliness of new computer systems and the trend toward a distributive CAD/CAM strategies. In the near future, design and manufacturing engineers will have desktop computer systems, minimizing the role of the maintenance intensive large central host computers.

II. Site Preparation

The system manager must sit down with vendor technicians a few weeks prior to system delivery to determine the site installation requirements. In this meeting, the system manager should obtain information on the power requirements and the operating environment necessary for the computer installation. A typical computer installation site would be a dustfree, climate controlled room with anti-static carpeting or a raised floor. (Stark, 1986) The vendor will often supply the company with a site preparation manual. The system manager must make sure that the site preparation will be finished before the delivery date.

III. Training

Training should have been discussed during the system selection process and classes should be planned and scheduled soon after the sale of the system. The training should take place on three levels: upper management, system management and system user. (Arthur, 1985) The training can be performed by the vendor or a qualified third party.

Upper Management Training

By upper management, the author is referring to the individuals responsible for productivity of the engineering and manufacturing operations (ie. V.P. Eng.,V.P. Mfg.). This training should also be attended by the system manager. The training would consist of a one day class in which a vendor representative or a third party consultant would explain how the CAM will modify current business practices and discuss the changes that must be effected to insure a successful implementation. More importantly, this class will establish realistic expectations on the part of management with respect to productivity improvements and make them aware of the typical start up problems that occur. This training will prove well worth the cost during the implementation process.

System Management Training

This training can take place at the vendor or customer site and should be attended by the system manager and his chosen backup. It is better to have this training take place off-site so that the class will not be disturbed by on-going business interactions. If this training is done off-site it should take place no more than one week before the installation. If the training is done on-site it should take place as soon as possible after the installation. The class will consist of 3 - 4 days of training on the following concepts:

Operating system (Basic commands, File structure)
File maintainance
Backup procedures
Plotting procedures
System security

User Training

Again, this training can take place on or off site and should be attended by the system users. If this training takes place off-site it should take place no more than one week before the installation and it should be given on the same workstations as will be installed at the user site. If the training is done on-site it should be performed as soon as possible after installation. The class will consist of 1 to 2 weeks of application training. It would be nice to send all of the users to be trained in one session but this is usually not possible because it is neccessary to maintain on-going operations. If this is the case it should not be a problem to have the vendor perform two training sessions. Having the new users from the first session try to train the remaining people is strongly discouraged. It takes approximately six months of experience with the software before one is able to adequately train others. (Knox, 1983) The author also cautions that training should not take place too early before the system is installed. If the users are not using the system within two weeks after the training session they will have forgotten the majority of what they learned. Vendor support during the initial month of system use will be critical. As stated in the selection process it is important to evaluate a vendors support services before selecting a system. It will be up to the system manager to make sure his users are provided with adequate support.

Customized Training Material

After the users have become proficient with the software it would be a good idea to assign a user to develop a customized training booklet for future users. This material will save much time, money and effort when training a new user.

IV. Standards and Procedures

One of the *major responsibilities of the system manager* will be to establish and enforce standard practices and procedures to ensure effective system utilization. The following section discusses standards and procedures for the initial implementation and continued successful operation of the CAM system. These procedures were developed based on the prior experience of the author in implementing and working with these systems.

N/C Program File Storage

A standard convention for naming and storing files must be established to manage the many files created on the CAM system. There can be as many as 15 N/C program files associated with a single part and a good naming convention should allow a user to distinguish among these files to select the appropriate one. There are many possible conventions for naming files so, this section will concentrate on the requirements that a naming convention must fulfill. First the types of files associated with the CAM system will be discussed.

Geometry File

The input to the CAM system is the finished part drawing or geometry file output by the CAD system. This file will already have a name assigned to it by the engineering department. Depending on the naming convention being used by engineering, manufacturing can either rename the part or leave it as is. For the sake of consistency, manufacturing and engineering should try to establish a common naming convention.

Cutter Location Source File

The first file created on the CAM system is the cutter location source file. This file contains the postprocessor statements and motion commands usually in a COMPACT or APT like format. This file is the result of user interaction with the CAM system on the specific geometry file. Once this file is complete it is compiled by the postprocessor to produce the G-code file.

G-Code File

The G-code file is the output of the postprocessor and is the second file created on the CAM system. This is the file that will be read into the machine tool to tested and edited for a production run to produce the desired part.

Production Program File

It is rare that a program is completely correct the first time it is run on the machine. So, the next step is to debug the program on the machine and optimize it for a production run. Once the program has been run, it is uploaded to the computer for temporary storage. This creates yet another file which must be uniquely identified.

Program Setup Documentation File

This is a text file that contains the documentation that must be given to the machine operator in order to successfully run the program. This file is as important as the production program file since it contains the instructions to run the program on the machine tool.

A complex part can require five or more different setups each of which will require a separate cutter location source file, G-code file and a production program file. The complex programs may also contain sub-programs nested within them. All of these programs will also require job setup documentation which are essentially text files containing tooling listings and machine settings. Without a standard naming convention to uniquely name each of these files the part program database will become an unrecognizable mess with programmers preferring to recreate a program rather than try to find it.

To be effective a file naming convention for a CAM system must contain the following features:

- -Base filename to associate the part program with the corresponding part number assigned by engineering.
- -Operation designator to signify the operation for which the program is intended (front, back, side).
- -Sub-program designator to indicate that a sub-program is required by the main program. This will also be

used to differentiate among multiple sub-programs.

-File extension to differentiate among the file types discussed above.

There are many naming conventions which can be developed to accomplish the required objective. In the following paragraphs an efficient methodology for assigning file names is developed. Each of the features mentioned above will be discussed with respect to this methodology.

Base File Name

The purpose of this section of the filename is to associate the part program with the actual part design created by engineering. To maintain consistency manufacturing should try to structure their naming convention after the engineering naming convention. Engineering often uses part numbers for drawing file names. Manufacturing should consider using a subset of the part number as the base filename to minimize the length of the filename. The typical base filename length is 5 to 8 characters.

Operation Designator

The operation designator is a single character within the program filename to signify the operation for which the program was created. As mentioned previously, most parts require more than one setup on a machine to produce them.

The operation designator will identify the operation that each program is intended for. A standard code to identify the separate operations should be developed by the system manager.

Sub-program Designator

The sub-program designator is a single character used to signify the use of sub-programs within the main program and differentiate between multiple sub-programs for the same main program. The system manager will also be required to develop a code for this purpose.

File Extension

The file extension will be used to distinguish among the many file types created on the CAM system (cutter location source file, G-code file, etc.). A simple three letter extension on the end of the filename will identify the individual file types. Again, file extension standards must be established by the system manager.

N/C Program Archiving Procedures

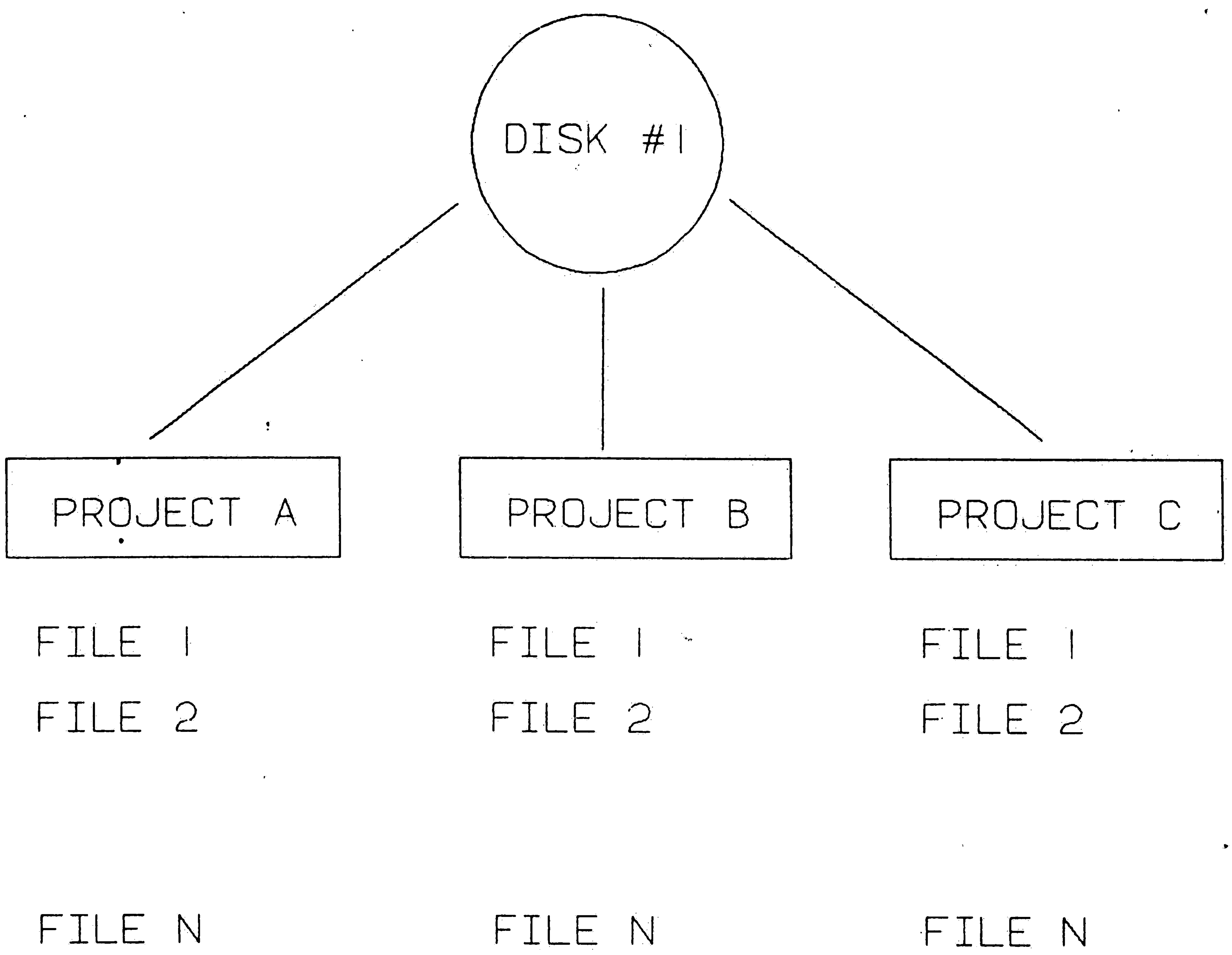
Once a standard naming convention has been established the system manager must develop procedures for storing part programs. This is necessary to maintain the integrity of the part program data base. Without standard procedures for file archiving the computer data base will become disorganized and overloaded with old programs. In addition, leaving many parts in on-line storage will decrease the performance of the computer and increase on-line storage cost. As the disk becomes overloaded the usual reaction is to purchase more disk storage. Often times what is really needed is a standard procedure for archiving old programs, deleting useless files and maintaining only current work in on-line storage. The next section proposes a methodology to accomplish this task.

Data Base Management

The system manager should create a directory for each project that is assigned to the machine shop. All files that are associated with a particular project are placed in that directory. This is an easy way for the system manager to keep track of project files. An example of this file structure is depicted in figure 3. After the project has been finished and the programs have been run all of the cutter location source files and the production program files in the directory should be archived to secondary storage. Secondary storage can be in the form of reel

FIGURE 3

DATA BASE DIRECTORY STRUCTURE



tape, cartridge tape or floppy disk, depending on the system being used. All of the setup documentation should be archived along with the part programs on a single tape or diskette labeled with the project name. The cutter location source file is stored along with the production program because it will be easier for the programmer to edit the CLSF file than the production G-code file when an ECO is issued on the part design. The programmer can also visually verify the CLSF file on the CAM system, whereas many systems can not graphically portray a G-code file.

Once the files have been archived they should be deleted from on-line storage. It is very important that only one copy of each file be maintained and all others deleted to preserve the integrity of the data base. A tape or diskette library should be kept in a secure place, preferrably fire proof, insuring that the storage medium is not exposed to extreme temperatures, excessive dust or magnetic fields. Some companies may also wish to keep a paper backup file in storage. This file would contain the latest blueprint of the part, a punched paper tape of the program and a copy of the setup sheet.

File Modification Procedures

One of the powerful features of the computer is the ability to retrieve and modify existing files to reflect changes in product design. (Groover, Zimmers, 1984) However, this ability must be carefully controlled and monitored to preserve data base integrity. File modification procedures must be established and enforced early in the implementation process. As part designs change so must the N/C programs and the associated documentation required to produce the parts. The next section proposes a technique for N/C program revision control.

Revision Control

It is very important for the machine shop to establish procedures to monitor and update part programs to reflect engineering change orders issued on existing part designs. By keeping N/C documentation current with ECO levels, the machine shop will avoid the costly mistake of running a production program at the wrong revision level. ECO procedures vary among companies but in general when designs modifications are approved by engineering, manufacturing is sent a notice and sometimes a copy of the modified drawing to update their files. If the modified drawing is not sent with the ECO, it is the responsibility of the shop forman to request a copy from the drafting department. Once the modified drawing file is obtained, a programmer should be assigned the task of updating the coresponding part programs and setup documentation. The procedure for updating the CAM data base is described below.

Cutter Location Source File

The first line in all part program files should be a note stating the part number and revision level that the program is to be used for. The programmer must call up the latest version of the CLSF and modify it using the updated drawing file obtained from the drafting department. The programmer should also modify the revision indicator at the top of the file to correspond to the latest revision level.

G-code File

After the CLSF has been graphically verified on the CAM system, it should be post processed to produce a new G-code file. Again this file should contain a note indicating the part number and revision level. This file will be downloaded to the machine tool for prove out and optimization.

Production Program File

Once the G-code file has been debugged and optimized on the machine tool, it should be uploaded to the CAM system data base to replace the old production program file.

Program Setup Documentation File

It is very important that the setup documentation files be modified to reflect the changes in program operation. The revision level on the program setup sheet must also be modified to remain consistent with the part program.

After all of these modifications have been made the programmer must delete all old files so that only one set of program files exists for each part. The updated files can then be stored using the file archiving procedures described earlier. It is important to establish file maintenance procedures early in the implementation process. Data base management is a tedious task however, a poorly maintained data base will lead to a multitude of problems causing people to lose faith in the systems capabilities. (Stark, 1986)

Standards to Facilitate the Integration of CAD and CAM

Establishing communication practices and procedures for data transfer between engineering and manufacturing is necessary to derive the maximum benefits from the CAM system. (Knox, 1983) These procedures would include the release of part designs to manufacturing for production as well as engineering change order notices for design modification. The computer can be used to enhance the flow of information between engineering and manufacturing making it more efficient and error free. The following section proposes a methodology for establishing standards to effectively interface CAD and CAM.

CAD File Formatting Standards

Many companies have invested in CAD systems solely for the purpose of automating the drafting department. (CASA/SME, 1985) In these situations where the main objective is plot creation there usually are no file formatting standards for data transfer. With the implementation of the CAM system there is now a need to electronically transfer information between the two disciplines. One of the benifits of establishing the CAD to CAM link is that geometric data can be passed directly from the CAD system to the CAM system for part program creation. However, the part programmers will only use portions of the geometry files created by the drafting department, specifically the geometry associated with each view of the part. The other data associated with the part such as dimensions, notes, drawing border, etc. are not needed in the geometry file for the creation of part programs and should not be transferred to the CAM system data base. This requires that the file be stripped of data considered to be extraneous to the part programmer before it is passed to the CAM system.

To effectively interface the two systems, standards must be established to facilitate this data transfer. The objective of these standards is to minimize the data manipulation required to input the geometry files to the CAM system. Establishing these standards will require a cooperative effort by the system managers of the CAD and CAM systems. The following paragraphs describe some of the standards that the author feels should be enacted.

Layering Standards

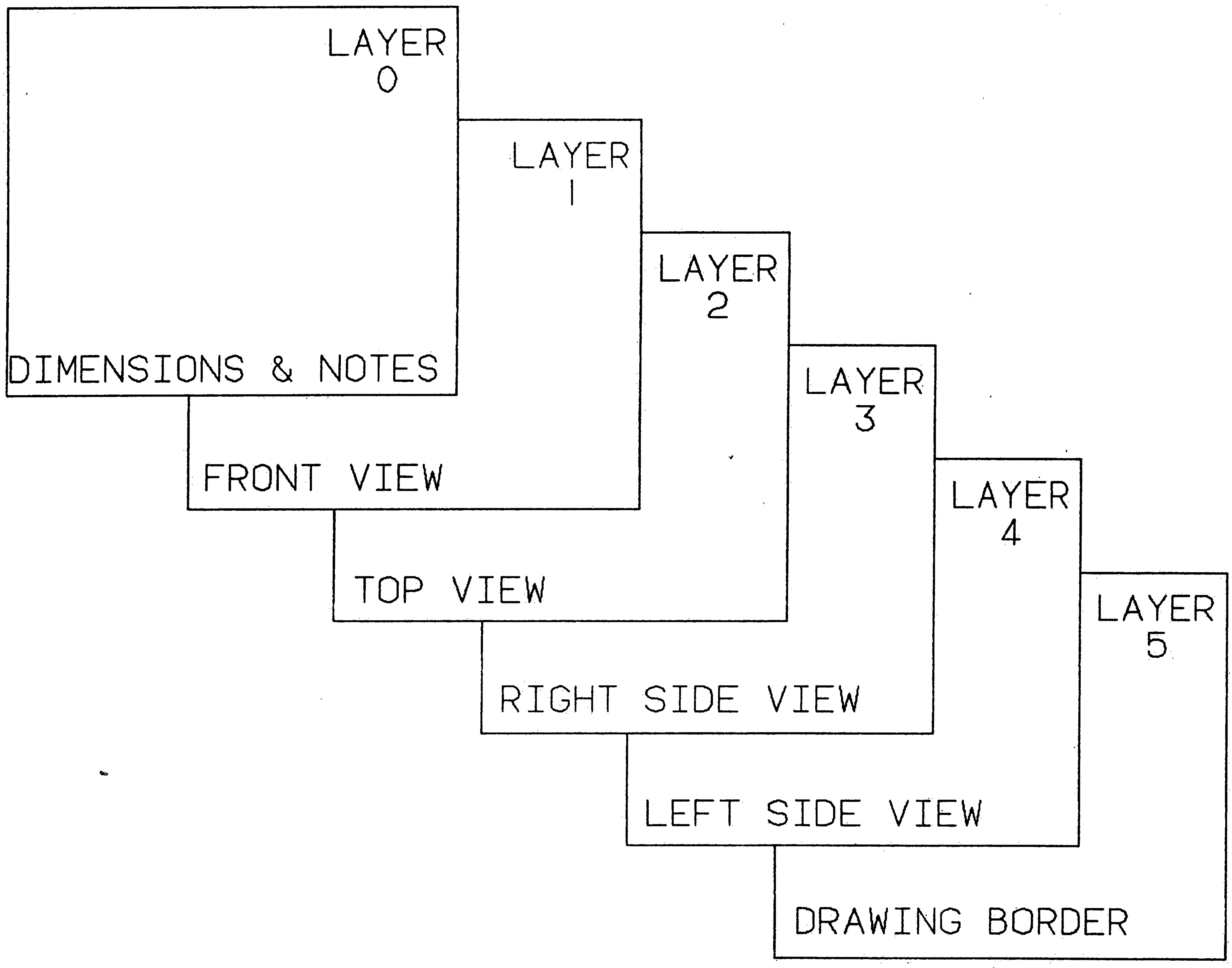
The majority of CAD systems available today have the ability to break a geometry file up into many separate layers. This capability can be used to the advantage of engineering and manufacturing by making large files much easier to view and manipulate. Layers can be compared to foils on an overhead projector in that they can be viewed collectively or selectively depending on what the user is trying to accomplish. For example, a user may place all of the part geometry on layer 1 and all of the dimensions on layer 2. It is now possible to view both layers together or individually if the user only wants to see the geometry. By establishing standard CAD drawing procedures, the system manager can have drawings formatted by the user with minimal effort on the users part. Formatting the drawings as they are created will save time and effort when the drawings must be manipulated for use on the CAM system. A typical layering scheme is depicted in figure 4.

Data Base Integrity

In addition, to organizing the files into layers for file manipulation, standard drawing practices should also be established to maintain the integrity of the CAD data base. As CAD/CAM systems are implemented, paper comunication between engineering and manufacturing will be replaced by electronic communication. Manufacturing will be working directly from the electronic drawing files created by engineering. Drawing standards and checking procedures

FIGURE 4

SAMPLE FILE LAYERING SCHEME



must be established to insure the integrity of drawings in the CAD data base before they are transferred to the CAM system. Typical standards would require that drawings are submitted to the machine shop at a scale of 1:1 with all dimensions acurate to 5 decimal places.

Production Release Practices

As mentioned previously, the implementation of the CAM system will change the manner in which engineering and manufacturing communicate. To cope with this change, the practices for releasing designs to manufacturing must be modified. Data transfer procedures must be established to provide an accurate, efficient and timely flow of information from engineering to manufacturing. These procedures will determine the contents of the design release package, along with when and how it will be released to manufacturing. A typical release package will contain design drawings, a bill of materials and a work order. The way in which this information will be transferred depends on the particular computer configuration. If the systems are tied together on a network, the data can be sent directly to the CAM system. Without a network the data will have to be placed on a secondary storage device such as a diskette or a tape, and loaded on the CAM system.

N/C Program Documentation Standards

When releasing part programs to machine operators it is important that the program documentation provided is clear, complete, up to date and in a consistent format. Using manual programming methods it is more difficult for the shop forman to maintain standards among many programmers. Machine operators would have to decipher the varying program documentation that they received from the different programmers. This documentation can be hard to read or incomplete. Providing this information will become an easier task with the use of the CAM system. The computer will reduce the effort required to create and manipulate program documentation while allowing the system manager to establish standard document formats.

Standard text files can be created on the system for the programmer to call up and fill in the necessary information. The file can then be printed for use by the operator. This will maintain consistent document formats among programmers. The end result will be more legible and consistent documentation that will be easier for the machine operators to understand. A sample format file is depicted in figure 5.

Figure 5

Standard File for Setup Sheet Creation

P/N:
Description:
Operation:
*Stock for Ordering:
*# of Parts per Stock:

Program #:
Program File:
Subprogram #'s:
Subprogram Files:
*# of Parts Needed:

Gages:

Tools:

Offsets:

Fixture:

Notes:

Date	Setup Start Time:	Setup Finish Time:	Run Start Time:	Run Finish Time:	# Good	# Bad

Operator Comments:

*Operation 1 Setup Sheets Only

Old Program Conversion

Prior to the advent of magnetic medium storage devices N/C part programs were stored in G-code format on punched paper tape. These programs were fed into the machine through a tape reader interfaced to the machine. The question will arise as to how and when to convert these programs to computer storage. The author feels the best way to approach this problem is to convert old programs as they are used or modified. For example, if an old program is called out for a production run, after the job is complete the production program can be uploaded to the computer for storage. The setup documentation should also be revised at this time to the standardized format on the computer. If an old program must be modified it should be reprogrammed on the CAM system and the old program should be discarded. This is a much more cost effective method of program conversion than assigning an individual to the full time task of converting old programs.

Initial Project Selection

The first project to be completed on the new system should be carefully selected because the outcome of this project will have a lasting effect on managements confidence in the systems abilities. The project selected should not be overly complex or require new production techniques. Projects that are already behind schedule should be avoided. This is the first chance to show off the new system within the company and the opportunity should not be missed. (McDonald, 1984)

Chapter 6 Evaluating System Performance

The application of computers to conventional manufacturing methods can provide benefits that include improved productivity and quality control, operating flexibility and reduced direct labor. To be able to measure these benefits procedures must be established to track and measure system performance. Tracking system performance in a verifiable manner is necessary to compare actual performance with the company's initial projections and to correct system inefficiencies. The following section proposes a methodology for monitoring system use to ensure maximum performance.

Scheduling System Use

By allowing system usage on an as needed basis the system manager will be unable to track user or system performance. A scheduling system must be established to ensure that individuals are assigned on a daily basis to the projects that are most useful to the company. (Medland, Burnett, 1986) In this way the system manager can track the progress of the project and will be able to identify inefficiencies in system use. The department manager should be responsible for scheduling users based on project deadlines.

User Log

Once the users have begun a regular schedule of system use, the system manager must provide them with a means for generating feedback on system performance. (Quantz, 1984) This can be accomplished by keeping a user log. In this log the user will record the time spent on the system, the project worked on and any problems that occured during the session. This provides the system manager with documented evidence of system problems and use. This can also be used to point out system bugs to the software vendor. A sample user log is shown in figure 6.

User Support Group

For large system installations with more than ten full time users it will prove worthwhile to form a user support group. (Stark, 1986) This group will be responsible for catering to the needs of the system users, acting as a liaison between the users and the system vendor. The users will come to the user support group with software and hardware problems and the support group will be responsible

FIGURE 6

SAMPLE USER LOG

DATE	NAME	PROJECT	TASK	START TIME	END TIME	REMARKS
6/20	TIM	BOEING	HOUSING	9:00	11:30	TABLET DOWN

for solving these problems. By representing many users in this fashion it will be easier for the vendor to support the system.

Comparing System Performance to Conventional Methods

When evaluating system performance it is important not to focus only on direct labor savings. Indirect benefits such as improved product quality, decreased N/C program prove out time, reduced fixture design time and increased machine utilization should also be considered. (Tombari, 1984) In most cases, procedures for monitoring these variables have already been implemented. Establishing performance measures to determine the actual gains achieved with CAM is difficult. It is felt that the best way to evaluate system performance is to track the new production cycle time using the data collection methods described above in conjunction with previously established methods for tracking shop efficiency and product quality. The total production cycle time should include programming time, fixture design time, machine run time and any rework required. This data can then be compared with the data recorded for manual methods. This comparison will require that accurate and verifiable data collection methods be established.

It will take 6 to 12 months before the users become proficient with the new system. During this time period it is important for the system manager to monitor their progress. If some of the users seem to be lagging behind they may need more training or more system time. When the users become frustrated with the system they will revert back to manual methods which spells disaster for the system implementation. By carefully monitoring user progress, this problem can be avoided.

Chapter 7 Case Study

I. Background

The following chapter discusses the implementation of a CAM system by a manufacturer of LCD displays, which will be referred to in this case study as Company A. The methodology developed in this thesis is applied to the implementation and a conclusion is drawn based on the results. Due to the circumstances of this case study, the system selection portion of this methodology was not applied. However, the selection process carried out by Company A is discussed to illustrate some of the typical oversights made by companies investing in CIM technologies.

Company A is vertically integrated, designing and manufacturing all components associated with their display modules. At the time of this study, business was going well, but Company A was experiencing the typical pains associated with rapid growth. For approximately two years, they were using an in-house microcomputer based CAD system for design creation and documentation. Using this system, paper plots of part drawings were created by engineering and sent to manufacturing, where they were manually programmed to run on any one of four available CNC machines. Module production was running far behind schedule. Many display modules were being delivered anywhere from 9 to 12 months late. Management decided that one area of needed improvement was prototype and production part program creation in the machine shop. The average lead time for program creation on a new module was 6 to 8 weeks. Management reasoned that a CAM system would substantially reduce part programming time by eliminating the need for the programmer to recreate part geometry and by allowing the programmer to reuse and modify similiar part programs instead of starting from scratch. With this in mind, the company decided to invest in a CAM system that would interface to their CAD system for N/C part program creation.

II. System Selection

The selection process that ensued was random and disorganized. Because the entire company was rushed to keep up with production demands, the time was not taken to form an interdepartmental committee to evaluate the company's automation needs. Instead, a one man committee consisting of the shop foreman was formed. With no input, other than four vendor names, from the manager of the CAD system the shop foreman sat through demonstrations of four systems. A technical specification was not developed nor was a benchmarked performed. The only evaluation criteria used was the systems ability to accept geometry from the existing CAD system. Other than geometry transfer, price was the main consideration. Based on these demonstrations the foreman recommended the least expensive system, which was eventually purchased by the company.

III. System Implementation

The system purchased consisted of one microcomputer, one printer, software for toolpath generation, software to communicate with the CAD system and software to communicate with the CNC machines. The system was installed in the foreman's office, adjacent to the machine shop. From the start, management decided that the shop forman would be responsible for implementing and managing the new system. A three day training session was scheduled for the programmers. However, because of the backlog of production work, it was decided that only the foreman would attend the training session with the intent of teaching the others what he had learned when the work schedule permitted.

After receiving brief training from the forman, the users were immediately asked to use the system to program new display modules that were being rushed through production to meet a delivery date. When the programmers began work on these modules they learned that the interface to the CAD system left much to be desired, requiring them to edit and rework the drawing files. In addition, it was discovered that some of the programming techniques used by the shop were not supported by the system. Not feeling very confident on the CAM system, the users reverted back to manual programming methods, afterwhich the system sat idle for two months. It was at this time that management decided to call in outside help.

An outside consultant was called in to provide technical assistance on the implementation of the CAM system. The following section outlines the steps taken to implement the system.

Implementation Strategy

A strategy was developed for the implementation of the system. This strategy consisted of two phases incorporating the following areas:

Phase I

Training
System Management
System Training

Phase II

Standards and Procedures
CAD Practices for File Transfer
N/C Program Archiving Procedures
N/C Program Revision Control
N/C Program Release Package
Evaluating System Performance

Phase I

The first phase of the implementation established management responsibilities and developed the training programs necessary to educate machine shop personnel on system use.

System Management

Because of the size of the system purchased it was decided that a functional management strategy could best be applied. This strategy would require the shop foreman to manage the CAM system. Eventhough the shop foreman was relatively inexperienced with computer technology, the microcomputer based system was fairly easy to learn and maintain. Since only one system was purchased, the maintenance responsibilities were not very great. The system manager was to be responsible for managing the program data base, file backup, program revision control, program release control and scheduling system use. To prepare the foreman for this task a training class was developed.

System Training

Training was performed by the consultant and was carried out on two levels. One level was offered to the shop foreman on system management while the other was offered to the system users on the CAM software.

The system management training took one day and covered data base management, file transfer, file security, etc. This training had not been covered by the vendor in the training session attended by the shop foreman. The training was performed on-site. The only problem experienced during this training was the constant interruptions for the forman to attend to on-going operations.

The user training was attended by two programmers and also took place on-site. This time, it was arranged so that the programmers would be allowed to train without constant on-going business distractions. The training covered geometry file manipulation, tool path generation and verification, and post processing. The training went on for three days with few interruptions.

Phase II

The second phase of the implementation, developed standards and procedures that would have to be implemented by company A to effectively utilize the CAM system. To accomplish this task the outside consulting group was asked to document these procedures as they would apply to company A. The following section contains the documents developed for Company A.

CAD Practices for File Transfer

This document formulates the practices and procedures necessary to facilitate the transmission of data created by engineering services using the CAD system to the CAM system which is used by the machine shop for NC programming. The NC programmers only need a subset of the data created by engineering services, specifically the geometry associated with each view. It is therefore necessary to breakout the information created by Engineering Services on to separate layers so that data relevant to the machine shop can be easily drawn from the part drawing data base. The objective is to simplify the data manipulation required to prepare drawings for input to the CAM system while minimizing the transfer of inaccurate and extraneous data.

There are two ways to approach this problem:

1) Have Engineering Services modify their current practices so that drawings are created in the proper format to be passed to the CAM system.

2) Have the programmers in the machine shop become proficient enough with the CAD software to modify the drawings themselves.

Evaluation of the Two Methods

Engineering Services

In order for Engineering Services to perform the task of preparing drawings for the transfer to the CAM system some drawing procedures will have to be established. The benefit of this method is that the drawings will be created in the correct format the first time through and no drawing modifications will be needed. In addition, some needed drawing standards will be implemented making drawing files easier to manipulate and understand. The detriment associated with this technique is that the people in Engineering Services are not completely aware of how the CAM system works to be able to distinquish between required and extraneous geometry. In addition, they are not familar with the various machining techniques used in the machine shop which can effect the way the drawing file is set up before being passed to the CAM system.

Machine Shop

In order for the programmers to perform the conversion task it will be necessary to train them in the use of the CAD Software. If they are given part drawings in their current format much time will be spent reformatting these drawings.

The benefits associated with this method are that the programmers will have a better understanding than the draftsperson as to what geometry is relevent and how to set up the file to accomodate particular machining techniques.

Recommendations

The most efficient way to accomplish this conversion task would be through a compromise solution. Drawing procedures would be established by Engineering Services requiring the use of specified layers to break up the drawing views. The drawings would be given to the machine shop in this format which would eliminate the rework required using the current procedure. From this point the programmers would complete the conversion to neutral files and finally to CAM files, using their knowledge of how the CAM system works.

Current Procedures

Presently, there are no set procedures as to how part drawings are created. Each operator has an individually preferred method of organizing file layers for drawing creation with the single common goal of obtaining an accurate plot. Often times one layer will contain more than one view of the part and layer content will depend on the operator who created the drawing. With the implementation of the CAM system in the machine shop the part programmers will no longer be working strictly from a blue print but from the electronic data that is passed from the CAD system. This will make it necessary for all drawings to be modified to eliminate data not needed by the programmer (Dimensions, Notes) before being input to the CAM system. In addition, it will be essential for the geometric data created by Engineering Services to be complete and accurate.

The following procedures establish a set of guidelines to be followed by Engineering Services for the creation of part drawings that would ease the transmission of data to the CAM system. These procedures are outlined in list 3.

LIST 3

CAD File Formatting Procedures

1. Place each view in the drawing on a separate layer (Fig. 4). It is necessary to separate each view to facilitate the transfer of geometry to the CAM system because each view is brought into the CAM system as a separate file. By segregating the geometry on different layers it makes it easier to isolate the geometry required for each file. The layering format should be established as a set procedure by engineering services.

2. Dimensions and drafting notes should be placed on a layer separate from the geometry so that they can be easily segregated from the geometry needed by the programmers. This information is not needed by the programmers and will only impede the transfer process.

3. All the geometry should be at a scale of 1:1 and should be checked for accuracy. It is imperative that when drawings are modified the draftsperson does not just change the dimension value but, the geometry as well. If the integrity of the geometry is not maintained it will have a direct effect on the part programs created on the CAM system.

4. A Diskette containing all of the part drawings required for a specific module should be given to the machine shop in the format specified above along with their associated blue prints.

5. The machine shop will then be required to define part zero and create a neutral file of the part drawing for translation to the CAM system. Once the neutral file has been created the separate layers corresponding to each view can be transferred to the CAM system to create individual files for the machining operations required. In this way, each file will contain only the geometry needed for each separate NC program. As the separate layers are read in to the CAM system they should all be named after the part number with a letter at the end to distinquish each view file. Naming conventions are discussed in the NC Program Storage document.

Layer Control

It will be necessary for engineering services to establish a standard procedure as to how layers will be organized. In addition, a layer naming convention should be established so that layers designated for the different views on a drawing will have consistent names. By establishing standards such as these it will be easier for the programmer to understand the files that are created by the various drafts personnel.

Controlling Data Integrity

In order to preserve the integrity of the part data base a procedure should be developed for modifying drawings as ECO's are issued. It is imperative the geometry on the drawing is changed to reflect the design change. The programmer must rely on the draftsperson to transfer accurate data to the machine shop for this process to work.

N/C Program Archiving Procedures

It is important that a methodology be developed to archive N/C part programs and their associated documentation. This document describes the file types that will be encountered when using the CAM system and establishes a naming convention for these files. A procedure is established for the archiving of N/C programs and documentation. This procedure can be applied to existing and future programs. Revision control is not discussed in this document. This topic is covered in the Program Revision Control document.

FILE TYPES

Drawing File (DWG)

These are the part drawing files that are passed from Engineering Services to the Machine Shop in the format specified in the CAD/CAM Practices document. These files contain the original part geometry which is used for part program creation on the CAM system. All of these files are characterized by a .DWG extension.

Drawing Exchange File (DXF)

These are neutral files which facilitate the transmission of drawing files to the CAM system. All CAD part drawings must be converted to the exchange file format before they can be read into the CAM system. These files are characterized by a .DXF extension.

Cutter Location Source File (CLS)

These files contain the part programs in the high level APT language as opposed to low level G-code. The CLS file will also contain the setup sheet for the part program. The setup sheet can be placed at the top of the CLS file using the N/C editor. All cutter location files have a .CLS extension.

Cutter Location File (CLF)

This file is created automatically by the CAM system whenever a CLS file is created by the user. This file is also automatically updated by the system whenever the language file is modified. All of these files have a .CLF extension.

Tape File (TAP)

This is the G-code file created when the Cutter Location file is post processed. After final checking this file is transmitted to the CNC machines to create the part. A comment line should be placed at the beginning of this file stating the part number and revision level for which the program is used. All of these files have a .TAP extension.

Tape File Returned From Controller (TRC)

This is a tape file that has been proven out and uploaded from the controller to the computer. These files are given a .TRC extension. TRC files are temporary files that should be converted to PRD files after the prototype run is complete.

Production Tape File (PRD)

This is a .TRC file that has been modified for a production run. Modifications might include changing the program from single to dual vise operation or speed and feed optimization. All of these files have a .PRD extension.

FILE NAMING CONVENTIONS

Drawing Files

CAD drawing file names are based on the engineering part number. Part number standards are available from Engineering Support Services. For use on the CAM system, the grouped geometry in a drawing file is written to a new drawing file with the same name as the parent file except all zeros are dropped and a "W" is appended to the end of the filename.

For example:
DC-100-005.DWG would become
DC-1-5W.DWG

Drawing Exchange File (DXF)

When a DXF file is created from the "W" file discussed above the same name is kept and the system tacks on a .DXF extension. If there is a need for multiple DXF files a letter can be appended to the end of the file name. The lettering conventions are discussed in section 5.2.3.

CAM System Files

CAM file names consist of four components:

- Condensed Part number
- Operation Designator
- Sub-program Designator
- File Extension

The rules for naming CLS files follow:

Condensed Part Number

For a part with a drawing number of the form cc-dnn-nnd where:

c = 1 letter from {A..Z}
d = 1 digit from {1..9}
n = 1 digit from {0..9}

The CLS filename will be:

ccdn-ndox.CLS

If the value of n is zero it is dropped from this file name. The rest of this filename is described below.

Operation Designator (O)

This is a letter within the filename which specifies the program operation on the part (e.g. Front, Back, End, etc.). This letter is equal to one of the following:

F = Front Operation
B = Back Operation
E = End Operation (If only one)
R = Right End Operation (If more than one)
L = Left End Operation (If more than one)
X = Fixture Program
S = Side Operation
C = Connector Details

Sub-Program Designator (X)

This is a number used to signify the use of sub-programs within the main program and differentiate between multiple subprograms for the same main program.

> X = 0, as part of the main program filename this indicates that the main program has sub-porgrams associated with it.
> X = a single digit if it is part of a sub-program file name. The value of the digit would correspond to the sequence of the sub-programs. For example:
>
> X = 1 (first sub-program in main program)
> X = 2 (Second sub-program in main program), etc

If the main program does not have any sub-programs then the digit would be dropped from the filename.

File Extension

The file extension distinguishes the many file types associated with the CAM system.

.CLS - Cutter Location Source
.CLF - Cutter Location file
.TAP - G-code tape file

These extensions are automatically placed on the end of the filename by the CAM system when these files are created.

.TRC - Tape return from controller
.PRD - Production ready program

The extensions must be appended to the end of the filename by the programmer when the program has been modified.

Sample Part Number: DB - 100 - 015

Drawing file: DB-1-15W.DWG

DXF file:	DB-1-15W.DXF	
CLS file:	DB-1-15FO.CLS	(Front operation with sub-programs)
	DB-1-15F3.CLS	(Filename for the third sub-program for the front operation)
	DB-1-15F.CLS	(Main program with no sub-programs)
CLF file:	DB-1-15FO.CLF	
TAP file:	DB-1-15FO.TAP	
TRC file:	DB-1-15FO.TRC	
PRD file:	DB-1-15FO.PRD	

N/C Program Archiving Procedure

The archiving procedure for part programs can be broken down into two areas:

Floppy disk storage
Paper storage

Floppy Disk Storage

The CLS and PRD files for all of the components contained within a module should all be stored on a single diskette marked with the module part number. Keeping all of the module parts on a single diskette will make file storage and retrieval an easier task. The CLS files are stored along with the PRD files to simplify the task of program modification. As ECOs are issued it will be easier to modify the CLS file than to edit the G-code file. The PRD files should have comment lines at the top stating the part number and revision level for which they are used. This will make it easier for the operator to identify them once they are downloaded to the controller. A diskette library should be kept in a secure place which is not exposed to extreme temperatures, excessive dirt or magnetic fields. Once these files are stored away on floppy disk all other copies of these files should be deleted. It is important that only one copy of each file exist for each revision level. In addition to preserving file integrity this will prevent the hard disk on the PC from becoming overloaded with file copies. By minimizing the number of files on the hard disk the performance of the PC will be enhanced.

Paper Storage

In addition, to computer files a paper file should be kept as a backup. One large master file will be kept for each module. This master file will contain sub-files for each individual component within the module. Each sub-file will contain the following:

Setup Sheet

The setup sheets for the last three production runs will be kept in the file. Referring to the time blocks on the setup sheets will help the foreman with shop scheduling and costing.

Blue Print

The marked blue print will also be stored in the file. It is important that the drawing is kept current with the latest release level.

Punched Paper Tape

The paper tape will be the backup for the floppy disk file in case a disk is lost or destroyed. The tape should be placed in a plastic case for secure storage.

Pre-existing programs are currently stored in this paper file format with a copy of the setup sheet, part drawing and punched tape. It is not necessary to read these programs into the computer to create a floppy disk library. These programs should be left in the paper file format specified above. However, as these programs are read back into the controller to be modified for new revision levels the modified programs should be stored on floppy disk as well as paper tape.

N/C Program Revision Control

It is very important for the machine shop to carefully monitor and update part programs to reflect Engineering Change Orders issued on existing part drawings. This is required to avoid the costly mistake of running a production program at the wrong revision level. It is necessary to establish a procedure to be followed when ECOs are issued to insure that programs are kept current with the latest part revision. This document formalizes a procedure to track revision levels and prevent the occurrence of this problem.

This section outlines the procedure to be followed when updating N/C part programs and their associated documentation to a new revision level. The items which must be updated are listed below:

Part Drawing

Upon receiving an ECO it is the machine shop's responsibility to obtain an updated blueprint of the affected part from Engineering Services. The ECO should be kept on file in the machine shop. A copy of the ECO along with the modified blueprint should be immediately placed in the paper file that is kept for the particular part. This will act as a flag to the foreman when scheduling production runs that a particular part program must be modified before the program is run. When scheduling production the foreman must check these files carefully.

CLS File

The programmer must obtain a copy of the CLS file from the last program revision. This LOG file should be stored in the floppy disk library on a diskette marked with the module part number as discussed in the N/C Program Storage document. It is easier for the programmer to modify the existing CLS file than to transfer a new part drawing over to the CAM system.

Setup Sheet

The setup sheet is stored as part of the CLS file as discussed in the N/C Program Storage Document. Once the program has been modified the setup sheet must be edited to reflect the program changes. Changes might include tooling, fixturing, etc. It is imperative that the new revision level of the program be added to the part number at the top of the setup sheet. The part number revision level will indicate the current revision level of the part program. Storing the program and the setup sheet together will help the shop foreman track program revision level.

PRD File

Once the modified program has been proven out on the machine tool and is production ready the old PRD file should be deleted. The new PRD file should be stored on the floppy disk for the module along with the modified LOG file. The comment line at the top of the PRD file should reflect the latest revision level. The naming conventions for the new PRD and LOG files remain the same.

Paper Storage File

The following sections describe modification that should be made to the paper storage file for a particular part after the part program has been modified.

Part Drawing

Once the program has been modified the old part drawing should be discarded and repaced with the new print.

Paper Tape

A new paper tape should be made for the modified and proven PRD file. The old one should be discarded. The label on the tape should indicate the revision level.

Setup Sheet

Setup sheets for the last three production runs should be kept to aid the shop foreman in estimating production run times.

N/C Program Release Package

When releasing part programs to the machine operators for production runs it is important that the packages provided to them are complete, up-to-date and in a consistent format. Providing this information will become a much easier task with the use of the computer in the machine shop.

The computer will reduce the effort required in the creation, storage, retrieval and manipulation of this data. Using the computer it will be possible to implement program release package standards while making it easier to control program revision changes. The following report documents program release procedures and recommends release document formats.

Setup Sheet

Imperative for successful program operation, the set up sheet is a very significant item in the program release package. This sheet provides the operator with the necessary information to run the program such as: the tooling required, machine offsets, fixturing required and so on. It is imperative that these set up sheets be easy to understand and consistent in format. The set up sheet should also be used to record program performance and required set up time for each run.

Figure 5 illustrates the format of the set up sheet recommended for use in the machine shop. The format is discussed below.

P/N:

Engineering part number with revision level. The P/N is used to identify the part and associate all information related to the part for easy retrieval from the computer upon demand. File storage procedures are described in detail in the N/C Program Storage document. It is important that the part revision level be included in the P/N for program revision control.

Description:

Brief description of the programs function for easy recognition during retrieval. For example, does the program create the deep pocket on a housing or just drill the mounting holes.

Operation:

To indicate the current operation among the total. For example, Operation 2 of 4, indicating the 2nd operation with two to go.

Stock for Ordering:

Only placed on the setup sheet for operation 1 . This indicates the raw material stock size which must be used for the first operation.

Number of Parts per Stock:

Only placed on the first set up sheet, this the number of parts expected from each piece of stock in multiple parts per vise programs.

Program Number:

Program number associated with part program for operator identification.

Program File:

Computer file in which program is stored. The numbering convention for these files is described in detail in the CNC program storage document.

Subprogram Numbers:

Program numbers of any sub-programs used.

Subprogram File:

Files that contain the sub-programs.

Number of Parts Needed:

This is a number which is penciled in for each production run telling the operator how many parts must be produced.

Gages:

Indicates if any gages are required during program execution.

Tools:

Listing of tools along with corresponding offsets.

Offsets:

Machine offsets to define part zero (G54, G55 etc.)

Fixture:

Describes the fixturing required for program execution.

Notes:

Special notes to the operator.

Time Block:

Used to track set up time, program run time and program yield. This information can be used in future production scheduling and to detect inefficiencies in production runs.

Operator Comments:

Used by operator to make special notes and suggestions to the programmer. It is here that the operator would indicate any changes made to the program.

A setup sheet template file similiar to figure 7 can be created and stored on the machine shop computer. This file should be used for the creation of all setup sheets with the programmer filling in the required information. In this way a consistent format can be established for the setup sheets. In addition, when programs are modified the programmer can call up the old setup sheet, copy it into a new file and modify it accordingly to save time.

Part Program

The part programs should be downloaded to the machine controller before the production shift begins. It is important that the operator be given the correct version of the part program corresponding to the part to be produced. Methods used for program revision control are described in the program revision control document. The night shift operators should be provided with a tape of the program in case the version in the controller becomes corrupt during operation.

Part Drawing

The operator should be provided with a clean part drawing with critical dimensions that must be held noted. Some dimensions will have to be held tighter than indicated on the print in order to hold other dimensions in later operations. These dimensions should be noted clearly on the part drawing.

Fixturing

The operator should be provided with the fixturing required for program execution. This includes parallels, gages, support blocks, etc.

The operator should be provided with all of the above information at the start of each production run. Special attention should be given to the time block to record and track production run performance.

Evaluating System Performance

The following section formulates a procedure for recording and evaluating the performance of the CAM system. With these procedures the machine shop will be able to measure the productivity improvements obtained with the CAM system. Also, by tracking system performance the system manager will be able to identify and correct system inefficiencies.

System Scheduling

The system manager will be required to schedule system usage based on the shop work load and production deadlines. By scheduling system time the system manager will maximize the productive utilization of the CAM system.

Logging User Time

Having establised a regular schedule for the users, the manager should develop a standard form for the users to log system time. On this form the users will record the time spent on the system, the project worked on and problems experienced during the session. The purpose of this log is two fold. First, it provides an effective means for the system manager to track the time spent on the system. Secondly, it provides a method for the user to document software and hardware problems for system maintenance. A sample log is depicted in figure 6.

Tracking Machine Utilization

As described in the N/C Program Release Document the program setup sheet can be used to record the performance of the part programs on the machine tool. This data will include program prove out time as well as program efficiency and yield. This data will be required to evaluate the performance of the CAM system.

Measuring System Performance

When measuring system performance the system manager should consider the following areas:

Direct Labor Savings

The CAM system will decrease the time required for program creation by eliminiting the need to duplicate geometry and by making it easier for programmers to retrieve and modify old programs.

Machine Utilization

Allowing the programmer to verify tool paths on the screen, the CAM system will decrease program prove out time. The CAM system will also perform tool path optimization, decreasing program run time.

Product Quality

Being able to use the same geometry created on the CAD system will minimize programming mistakes and improve program yield and product quality.

Using the data collection methods described above the forman can track performance in each of these areas and make comparisons with conventional methods. In order to perform an accurate evaluation, disciplined record keeping must be stressed.

IV. Results

The case study illustrates some of the pitfalls experienced by companies investing in CIM technologies without a predefined strategy. Company A invested in a CAM system without a developed strategy for system selection or implementation. Because of this, the system selected did not fully meet Company A's expectations. The interface to the existing CAD system was incomplete and cumbersome. In addition, the systems program creation and verification abilites were limited.

The initial implementation of the system also went poorly with the programmers receiving inadequate training and insufficient time to build confidence on system use. The programmers were then assigned to a project that was already behind schedule. It was felt that this project represented an ideal opportunity to demonstrate the systems ability to reduce program creation time. Pressured by production deadlines and frustrated by a lack of experience on the CAM system, the users eventually reverted back to manual methods.

Fortunately, management had the insight to recognize the problems experienced during the initial implementation and realize that a major effort would be required to salvage the CAM project. At this stage of the implementation, the methodology developed in this thesis was applied.

This methodology consisted of two phases. The first phase concentrated on training machine shop personnel on the maintenance and use of the system. The training was performed on-site and the users were given ample time to become familiar with the system. Despite a few distractions to attend to on going operations, the training was a success. After the training the users felt much more confident applying the system to production programming.

The second phase of this methodology was concerned with modifying existing work procedures and establishing new ones to effectively utilize the system's capabilities while monitoring it's performance. Using the step by step procedures outlined in this case study, Company A made these changes and implemented standard procedures for system use. Standards were implemented for N/C program storage, revision control, and release, along with standards to facilitate the transfer of data from the CAD system. The implementation of these standards went smoothly and proved to be essential for the successful implementation of the CAM system. It was found that the major obstacle to a successful implementation was obtaining the commitment necessary from staff personnel and management to make the changes required to achieve the maximum productivity from the system.

The final implementation of the CAM system was a success. The results of this case study support the need for a predefined strategy for the selection and implementation of a CAM system. The CAM system has been in operation for 6 months and despite a troubled start, the system is meeting Company A's needs.

Chapter 8 Summary

This thesis proposed a methodology for the implementation of a Computer Aided Manufacturing system stressing the need for integration within a CIM environment. This methodology was developed to achieve the maximum benefits attainable from a CAM system implementation.

The methodology consisted of three main parts. The first part established a system evaluation strategy to be used by a company during the system selection process. In this portion of the methodology automation needs assessment, CIM plan development, system evaluation criteria and system benchmarking were addressed.

Part two of this methdology, dealt with the actual implementation and integration of the CAM system into an existing CIM network. CAM system management and training are discussed along with standards and procedures for effective system utilization.

The third part of this methodology developed procedures helpful for evaluating system performance after implementation.

Finally, this methodology was applied to an actual CAM system implementation. The methodology was used as a guideline for establishing new operating procedures to achieve the maximum benefits from the CAM system.

The methodology applied consisted of two phases. The first phase dealt with system training for the system manager and the users. The second phase concentrated on the development of standards and procedures for an effective implementation and incorporated the following areas:

CAD Practices for File Transfer
N/C Program Archiving Procedures
N/C Program Revision Control
N/C Program Release Control
Evaluating System Performance

The application of this methodology resulted in the successful implementation of a CAM system at Company A. These results combined with the outcome of the initial implementation effort attest to the need for a structured methodology to select a CAM system and implement the changes necessary for effective utilization of this technology.

The thesis research and the case study support the need for a unified strategy for the successful selection, implementation and integration of a CAM system within a CIM structure.

Chapter 9 Conclusion

It can be concluded that the methodology developed in this thesis provides a sound basis for implementing and integrating the elements of a Computer Aided Manufacturing system within a discrete manufacturing environment. The results of the case study support the need for a unified strategy for the selection and implementation of a CAM system to ensure integration with existing and future systems.

Based on the research done for this thesis and the case study, it can be inferred that many companies take a piecemeal approach towards implementing CIM technologies. When taking this approach companies must realize the need to develop an enterprize-wide strategy for the selection, implementation and evaluation of CIM technologies. This strategy will serve as a guide for coordinating these investments and developing a unified CIM structure.

In addition, companies must also realize the need to revise current operations to attain the maximum benefits from computer automation. Effectively implementating these changes will require a commitment from all levels of a business to make the new technology work. An integral part of acquiring this commitment is educating employees on the realistic benefits and changes that can be expected from computer assisted methods.

Of particular importance were the standards developed to integrate the CAM system with the engineering data base of part drawings. The case study exemplifies the need to establish standards to facilitate communication between different systems and thus develop a truly automated flow of information. Eliminating the re-entry of data in to the system is where some of the key benefits of the CAM system are realized.

Another item of importance was the training required for the use and management of the system. The case study demonstrated the need to adequately train personnel to effectively utilize the systems capabilities. This training will help to ensure a smooth transition to the use of the new system.

The approach developed in this thesis is recommended as a general approach for the implementation of Computer Aided Manufacturing technologies. It will be necessary to customize this approach to account for the uniqueness of the individual situations to which it is applied.

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Vita

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